FLEXLAB

Facility for Low Energy eXperiments in Buildings

A NEW NATIONAL RESOURCE FOR ENERGY-EFFICIENT BUILDING TECHNOLOGIES

A unique opportunity to collaborate with world-class research staff in development, simulation, and validation of efficient building technologies.

FLEXLAB will consist of building system test facilities to be located in new and existing structures at the Berkeley Lab.

FLEXLAB will allow users to:

- Conduct focused research or product development on single components or whole-building systems integration.
- Replace any building system such as exterior building envelope, windows and shading systems, lights, HVAC, energy control systems, roofs and skylights, or interior components such as furniture, partitions, and raised floors.

BERKELEY LAB

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Construction of FLEXLAB has commenced and will be *completed in 2013*. Berkeley Lab is seeking industry partners for the first experiments after launch.

Technical Capabilities

- **Four newly constructed testbeds**
  - **Two cells per testbed, 600sf each**
  - **One rotating testbed**
  - **One double-height 'big box' testbed**
  - **7000SF total new testbed construction**
- **Virtual design and visualization testbed**
- **Control hardware testbed**
- **Occupied plug-load and lighting testbed**

Exterior Testbeds

Interchangeable Envelope Elements

- South facing and portion of north façade including glazing and opaque assemblies
- Exterior/Interior shading devices
- Roof insulation levels

Commercial Interiors

- Variable ceiling heights to 11'6" above finished floor
- Potential for raised access floor to 2-ft height
- Partitioning for core/perimeter zoning, up to 3 zones per cell
- Two cells may be combined for larger floor-plan layouts

HVAC

- One air handler per cell
- Dedicated central plant for every testbed, chilled and hot water
- Reconfigurable zonal systems (VAV, fan coil, radiant panels, chilled beam, displacement, under floor)
- Thermally isolated radiant topping slab
- Up to three radiant in-slab zones per cell

Rotating Testbed

- Reconfigurable ceiling, HVAC, lighting, facades, access floor
- Resets position every 60 seconds to align with solar orientation for dynamic tests
- Enables testing at other orientations, e.g. west facing

High Bay Testbed

- Reconfigurable skylights and clerestories
- 25-foot floor to ceiling height
- 25ft x 25ft floor-plate for equidistant daylight measurement
- Accommodates interstitial floor for 2-story applications
- Double height replaceable southern facade

Data Acquisition (DAQ) & Controls System

- Local DAQ server per cell
- Ethernet and power raceways for cell sensors & instrumentation
- Telecomm services local to each cell
- Secure database per cell
- LabView based controls with custom sequence scripting tool
  - Base HVAC controls
  - Control sequences for other systems (lights, shades, etc.)
- Full monitoring and data visualization capabilities
- Controls interface capabilities for simulation and scripting language platforms

See back cover for details

Instrumentation (Partial)

- Power metering
  - HVAC, lighting, MELS at circuit and device level
  - Whole building, and end use level metering
- High accuracy thermal load measurement
  - Chilled and hot water flow meters with temp sensor at each cell
- Other high accuracy instrumentation
  - Occupancy sensors
  - Air supply flow measurements
  - Room pressure
  - Lighting & glare measurements
  - Envelope components, thermal measurements
  - Calibration capabilities
  - Weather station

Initial Fit Out Of Testbeds

- Each testbed's replaceable components will initially match performance characteristics of different eras, modifiable for project needs
  - 1980S ashrae (two cells)
  - 90.1-2010 (three cells)
  - Title 24 2013 (three cells)
  - Net-zero design (one cell)

Internal Testbeds

Occupied Lighting & Plug Load Testbed

- 3000 SF core & perimeter office space
- Two zones for comparative studies
- All lighting individually circuited, metered and programmable
- Easily replaceable fixtures (plug-in)
- Occupancy sensors: computer, cube and lighting zone
- Outlets individually circuited and controllable for task lighting & plug loads

Virtual Design Testbed

- Two rooms
- Four SmartBoards per room
- Teleconferencing and large-scale visualization capabilities
- BIM through BEM platform interoperability testing

Controls Hardware Testbed

- Lab bench environment with soldering station
- Robust networking infrastructure access
- Controls mockup, testing and measurement equipment

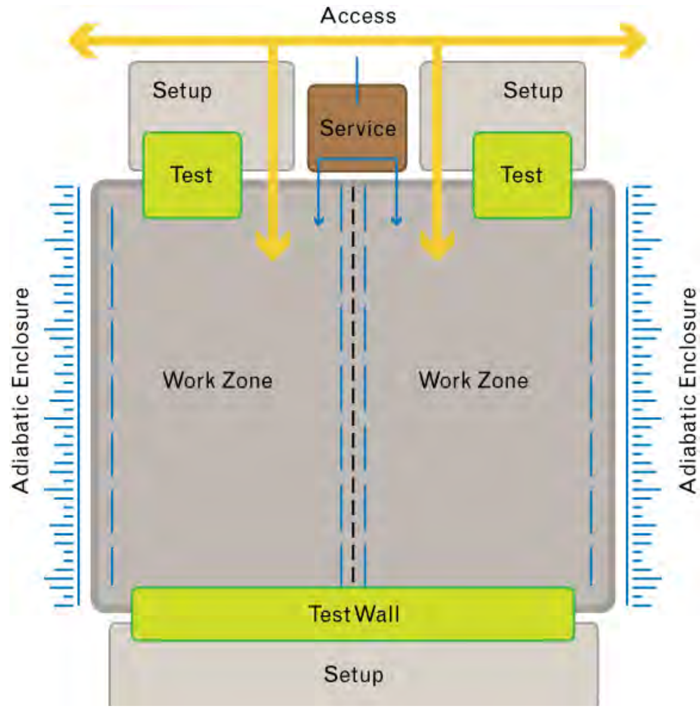
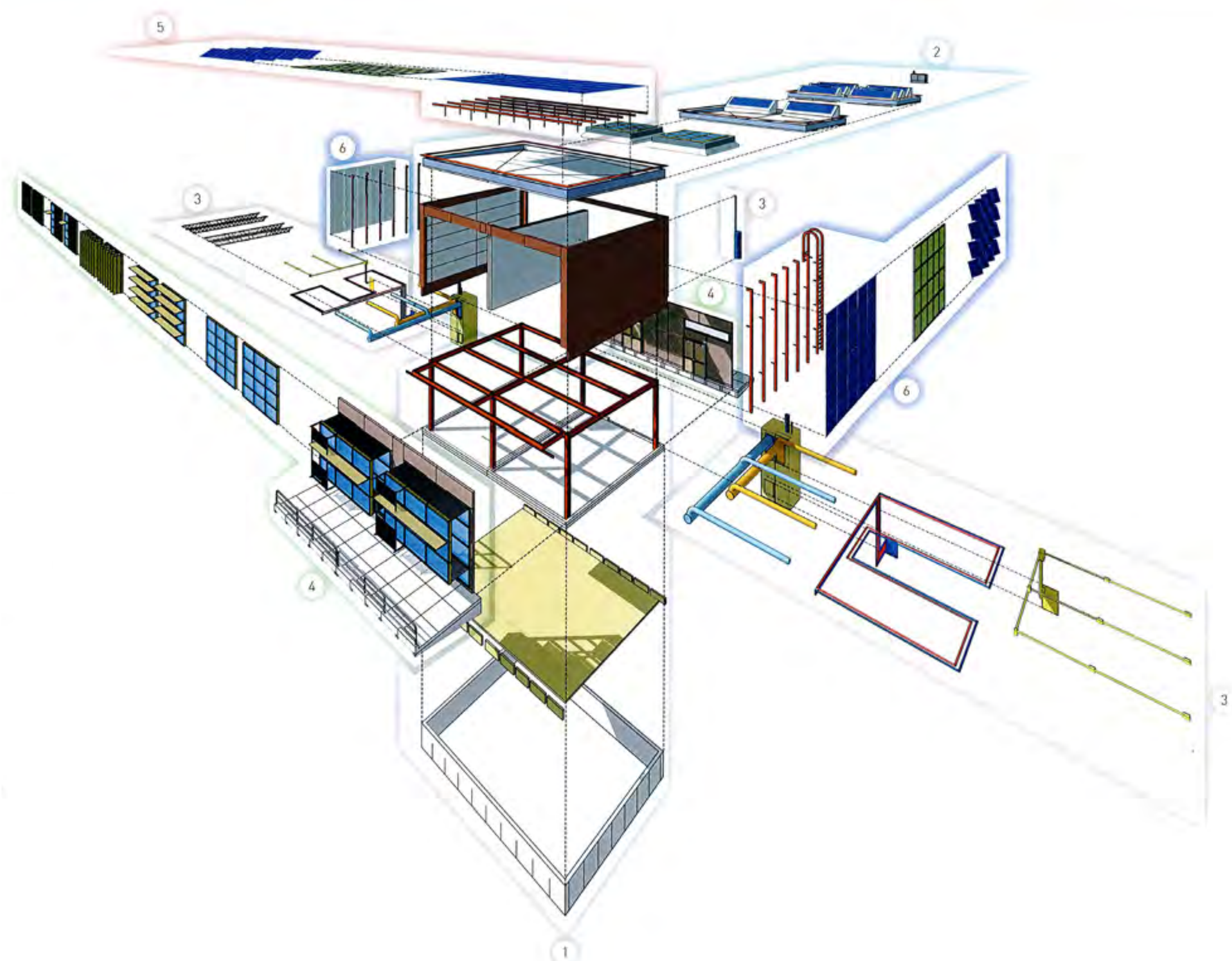


Diagram of exterior testbed cell showing access, setup, test, and work zones.



Exterior testbed exploded view concept.

FLEXLAB

Facility for Low Energy eXperiments in Buildings

FLEXLAB for Lighting – Use Case

Can industry reliably deliver high-performance lighting solutions at 1 kWh/(sf-yr)?

The Challenge

Lighting is one of the largest loads in commercial buildings, and low-power density (W/sf) installation requirements are increasingly common. However, gains in energy-efficient lighting of the size required for deep retrofit savings and zero-net energy buildings will require a shift to **performance-based metrics and design goals.**

What do designers, engineers, and manufacturers need to develop advanced lighting control systems capable of **delivering low-energy lighting solutions, while maintaining indoor environmental comfort** and occupant satisfaction?

FLEXLAB offers a unique opportunity for industry and researchers to collaboratively solve 'stretch' problems of this nature. **Consider the low-EUI lighting challenge**, and how **FLEXLAB** provides a path to solution that cannot be found anywhere else in the world.

Starting Point

A manufacturer has a **new lighting controls solution targeted for retrofit** applications that provides daylighting harvesting and occupancy control, setpoint tuning, and occupant personal control. The system has been bench-tested, component-tested, and function-tested in demonstration room environments. It has not undergone long-term performance testing with continuous high-resolution field-measured data.

Solution Pathway

System **performance validation in FLEXLAB's 1980s vintage testbed**, with identical side-by-side test cells.

The manufacturer conducts a six-month field test, leveraging testbed measurement capabilities for energy performance and occupant comfort assessments that were not possible in the manufacturer's company facilities.

Daylighting is integrated with artificial lighting through occupancy and lighting level sensors and controls.

Testbed Capabilities	Performance Parameters and Benefits
Horizontal and vertical photometers	Visual comfort – contrast, glare, ability to maintain worksurface illuminance
Lighting system and fixture power	System energy use, and peak demand; energy savings vs. 1980s base-case in twin cell; satisfaction of the 1kWh/(sf-yr) target
HVAC energy use	HVAC impacts; whole-building or zone energy savings due to retrofit system
Reconfigurable interior spaces	Impact of changing reflectance, geometries, and sensor locations
State of pre-existing shading devices (optional)	Impact of shading on energy and visual comfort
Exterior daylight conditions – cloud cover, irradience, sun position	Impact of exterior conditions
Robust data acquisition, accommodation of additional instrumentation	Flexibility to integrate experiment-specific measurement with existing testbed sensors
Ability to interoperate and execute control across a variety of platforms and devices	Flexibility to test diverse systems and components, control solutions, and proprietary systems

Immediate Outcomes

- Validated **system energy savings relative to the 1kWh/sf-yr target**.
- Optimized sequences of operation, energy and comfort performance metrics, whole building energy savings and HVAC dependencies.
- Holistic archival set of **high-quality field-measured data** (dozens of points) for use in manufacturer documentation and publications.
- Comprehensive experimental results to adjust system control logic, or component performance, if energy or comfort targets are not met.

Extended Validation & Deployment Opportunities

- Conduct a performance test in **FLEXLAB's rotational testbed** to determine performance under diverse orientations.
- Introduce occupants through **human subjects testing** – shift experimental focus to occupant satisfaction and personal control.
- Use the virtual design testbed, and simulation tools such as Modelica and Radiance to develop robust calibrated models; **partner with LBNL researchers with subject matter expertise**.
    - Use field-measured data to **extend experimental findings – diverse climates, room geometries, envelope, and HVAC systems.**
- Identify **critical performance drivers** and associated measurement solutions **for operational diagnostics, continuous commissioning, and reporting.**
- Build partnerships with **early-adopter FLEXLAB members** to conduct scaled demonstrations in real-world buildings across the nation.
- Use experimental data, in combination with access to **utility/state testbed members**, to expose benefits to new incentive programs and future code requirements.
- Provide anonymized system design and operational performance data to members of the **architecture & engineering community** using the virtual design testbed.
    - Industry-standard design and simulation tools support designers to gain confidence in specifying the low-energy retrofit lighting system.

References and Further Reading

Granderson, J, Gaddam, V, DiBartolomeo, D, Li, X, Rubinstein, F, Das, S. Field-measured performance evaluation of a digital daylighting system. 2010. Leukos, Journal of the Illuminating Engineering Society of North America 7(2): 85-101.

Wen, Y-J, DiBartolomeo, D, Rubinstein, F. "Co-simulation Based Building Controls Implementation with Networked Sensors and Actuators," Proceedings of the 3rd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Buildings (BuildSys'11), 2011.

FLEXLAB for Integrated HVAC – Use Case

Can industry increase the effectiveness of low-capacity, low-energy cooling systems for both retrofit and new construction applications?

The Challenge

Radiant cooling, chilled beams, displacement ventilation, and UFAD systems pose tremendous potential to lower cooling energy-use and deliver thermal comfort. However, adoption of these technologies has largely been limited to new construction applications in which thermal loads can be lowered, and controlled, when integrated with building envelope and interior lighting designs. These systems' capacity, and effectiveness, in meeting thermal load and comfort requirements of perimeter spaces, is a result of their interactions with the building façade and interior loads from lighting and other devices. Understanding how these elements affect system performance will illuminate opportunities to guide product, system, and controls design, and will suggest key upgrades to enable the use of these systems in retrofit applications.

For example, it has been understood that convection plays a large role in maximizing the cooling output of radiant panels or slabs. However, interactions and impact of convection that occur in typical buildings (e.g. convective effects from lighting systems and facades) are not well understood. With further insight into thermal performance impacts on radiant cooling, opportunities will emerge to **work synergistically with key lighting and façade retrofit systems to increase cooling effectiveness** under various operating conditions.

What do designers, engineers, and manufacturers need to develop advanced cooling systems capable of **delivering low-energy cooling solutions, while maintaining indoor environmental comfort** and occupant satisfaction?

FLEXLAB offers a unique opportunity for industry and researchers to collaboratively solve 'stretch' problems of this nature. **FLEXLAB** provides a path to solutions that cannot be found anywhere else in the world.

Chilled water supplied to a radiant cooling system.

Testbed Capabilities	Performance Parameters and Benefits
Horizontal and vertical interior surface temperature measurement	Air and radiant temperature distribution of the space, relates to thermal comfort
Room imaging and visualization	Space thermal distributions
Lighting system and fixture power	System energy use, and peak demand; energy savings vs. 1980's base-case in twin cell
Temperature and flow of HVAC utilities	HVAC thermal loads
HVAC energy use	HVAC impacts; whole-building or zone energy savings due to retrofit system
Reconfigurable interior spaces	Create multiple zonal conditions – perimeter and core applications
Reconfigurable glazing	Impact of glazing on convection, thermal loads, radiant cooling output, energy and thermal comfort
Reconfigurable shading	Impact of shading on convection, thermal loads, radiant cooling output, energy and thermal comfort
Robust data acquisition, accommodation of additional instrumentation	Flexibility to integrate experiment-specific measurement with existing testbed sensors
Ability to interoperate and execute control across a variety of platforms and devices	Flexibility to test diverse systems and components, control solutions, and proprietary systems

Starting Point

A manufacturer has a **radiant cooling product** and is interested in evolving its application in the retrofit and new construction markets. The radiant cooling product has been bench-tested, component tested, and demonstrated in a room environment, isolated from interactions with the wider array of building interior systems and convective sources. It has not yet undergone extensive long-term performance testing for interactions with, and impacts of, interactions with various grades of glazing and shading systems, with continuous high-resolution field-measured data.

Solution Pathway

System **performance validation** in **FLEXLAB** with identical side-by-side test cells.

The manufacturer conducts a field test, leveraging testbed measurement capabilities for energy performance and occupant comfort assessments that were not possible in the manufacturer's in-house facilities.

Immediate Outcomes

- Cooling & convective capacity effects of facades and lighting systems.
- Energy, thermal load and comfort performance metrics.
- Validation of sequences of operations, **system energy savings relative to a base case cell.**
- Holistic archival set of **high-quality field-measured data** (dozens of points) for use in manufacturer documentation, publications, and design information for practitioners.
- Comprehensive experimental results and information to adjust system control logic, or component performance, if energy or comfort targets are not met.

Extended Validation & Deployment Opportunities

- Conduct performance tests in **FLEXLAB's rotating testbed** to determine performance under diverse orientations.
- Introduce occupants through **human subjects testing** in the 1980s, 2010, 2013 or net zero testbeds – shift experimental focus to occupant satisfaction and personal control.
- Use the virtual design testbed and simulation tools, like Modelica, to develop robust calibrated models; **partner with LBNL researchers with subject matter expertise.**
    - Use field-measured data to **extend experimental findings to diverse climates, room geometries, envelope, and HVAC systems.**
- Work with LBNL researchers to **validate radiant cooling simulation algorithms** for use in annual energy simulation platforms such as EnergyPlus.
- Identify **low-energy controls and operations** strategies.
- Build partnerships with **early-adopter testbed members** to conduct scaled demonstrations in real-world buildings across the nation.
- Use experimental data, in combination with access to **utility/state testbed members** to expose benefits to emerging technology and new incentive programs, and for future code requirements.
- Provide anonymized system design and operational performance data to **members of the AE community** using the virtual design testbed.

References and Further Reading

Bourassa, N, Haves, P, Huang, J. A Computer Simulation Appraisal of Nonresidential Low Energy Cooling Systems in California, LBNL-50677.

FLEXLAB for Demand Response – Use Case

Linking energy-efficient operations with automated demand response

The Challenge

The vast majority of new, low-energy building systems have clear concepts for energy efficiency. For example, dimming lighting, radiant cooling, demand-controlled ventilation all have clear objectives for low-energy operations. Less well known are the requirements for designing, operating and automating low-energy systems for demand responsiveness.

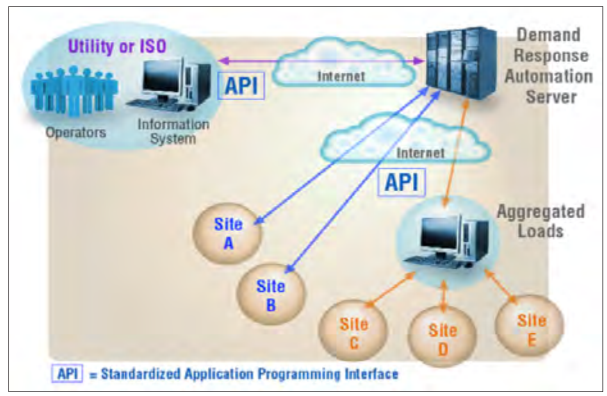
Consider **Demand Response (DR) control strategies** and how **FLEXLAB** provides a path to solutions that will help accelerate innovation. **FLEXLAB** offers high-quality continuous measurements combined with calibrated models of the facility to develop control strategies to evaluate how various sequences of operations perform at both the component and system level.

Starting Point

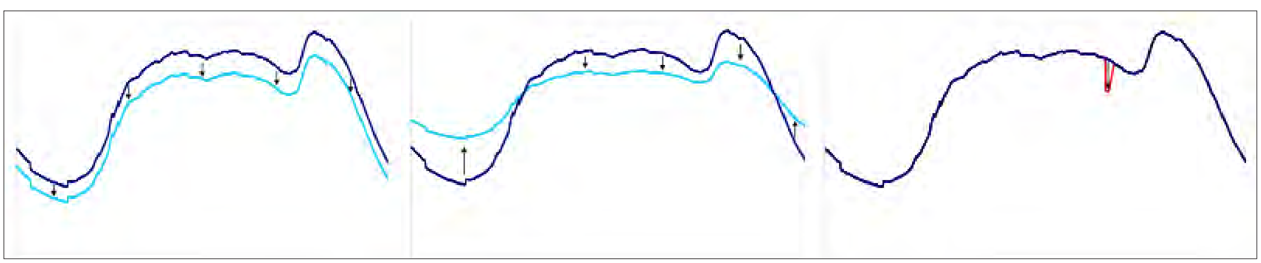
A control company or designer of a new “system” targeted for retrofit applications, that includes Automated Demand Response, lighting control, and advanced HVAC concepts. The system has been designed based on the capabilities of the components, but has not been tested as an integrated system.

Solution Pathway

The control company conducts a six-month field-performance test, leveraging testbed measurement and monitoring capabilities for energy performance and control strategy analysis to evaluate how the integrated system should operate in different modes – full service and full occupancy, reduced service, night time standby, and low-power.



An Open Automated Demand Response (OpenADR) communications test facility, part of FLEXLAB, incorporates a client-server automation architecture using an open application-programming interface.



Load shape modifications – energy efficiency, peak demand reduction, reliability response.

Testbed Capabilities	Performance Parameters and Benefits
Lighting system and fixture power and energy and demand	System energy use, and peak demand; energy savings relative to non-controlled 1980s retrofit base-case in twin cell
HVAC control and energy use	Zonal load measurement, hydronic or air
Robust data acquisition system to accommodate additional instrumentation	Flexibility to integrate experiment-specific measurement hardware with existing testbed instrumentation
DR automation server and client designs	Client-server capabilities, price and reliability signals, latency testing
Energy and demand response models	EnergyPlus and Modelica tools to model control strategies, HVAC, lighting, and whole “testbed” energy use

Immediate Outcomes

- Validation or optimization of sequences of operations.
- Demand Response capabilities analysis.
- Immediate results and information to adjust system control logic, or component performance, if energy or comfort performance is lower than target.
- Extrapolate results for diverse climates and related designs.
- Use holistic archival set of high-quality field-measured data for documentation and publication.

Extended Validation & Deployment Opportunities

- Explore a large variety of economic targets based on electricity tariff designs.
- Evaluate latency of control communications.
- Test interoperability with multiple control and automation and metering systems.
- **Partner with LBNL researchers** with subject matter expertise.
- Use field-measured data to inform critical performance drivers, and how to cost-effectively measure them, for as-installed operational diagnostics, continuous commissioning, and automated energy performance reporting.
- Build partnerships with **early-adopter FLEXLAB members** to conduct scaled demonstrations in real-world buildings across the country.
- Use testbed and early adopter data, in combination with access to **utility/state testbed members**, to share benefits for emerging technology and new incentive programs, and to inform future code requirements.
- Provide generalized system design and operational performance data to **members of the engineering community** using the virtual design capabilities.

References and Further Reading

Motegi, NA, Piette, MA, Watson, DS, Kiliccote, S, Xu, P. Introduction to Commercial Building Control Strategies and Techniques for Demand Response. Report for the California Energy Commission, PIER. LBNL-59975. May 2007.

Piette, MA, Ghatikar, G, Kiliccote, S, Koch, E, Hennage, D, Palensky, P, McParland, C. 2009. Open Automated Demand Response Communications Specification. California Energy Commission. CEC 500 2009 063.

Xu, P, Haves, P, Braun, J, Zagreus, L, Piette, MA. Demand Shifting With Thermal Mass in Large Commercial Buildings (Audit, Field tests and Simulation), December 2005. LBNL-58815.

FLEXLAB

Facility for Low Energy eXperiments in Buildings

FLEXLAB for Building Façades – Use Case

Can we create optimized façades that provide comfort, daylight and net zero energy performance?

The Challenge

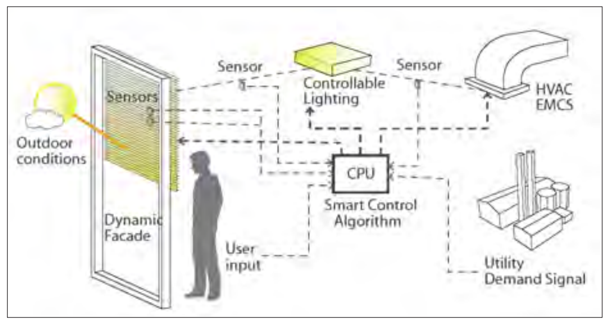
Optimizing the transparent elements in the building envelope to provide view and daylight, while minimizing winter heat loss, summer solar gain and glare, is a complex challenge. More stringent codes limit window size, but owners want large view windows. Dynamic solutions – smart glass, motorized shades and blinds, daylight redirecting systems – might help, but **there is enormous uncertainty in the actual performance of these dynamic systems.**

No one wants unproven solutions, but accurate field data are impossible to find. What do owners, designers, engineers, and manufacturers need to create smart and responsive façade and daylighting systems capable of **delivering net-zero energy performance, while minimizing peak cooling, maintaining view and providing visual and thermal comfort?**

FLEXLAB offers a unique opportunity for industry and researchers to collaboratively solve a wide range of performance integration and optimization problems. It allows **exploration of façade performance while varying and controlling every key design and operating parameter**: room parameters, façade features, occupied vs unoccupied, and HVAC/lighting interaction. Tests can be done in one-story spaces, two-story spaces or a rotating testbed that can be fixed in different orientations or moved to follow the sun.

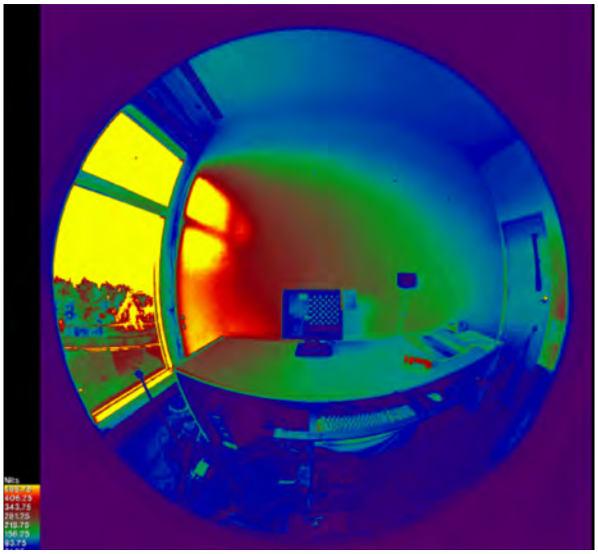
Starting Point

Imagine an innovative design team with a demanding client who wants a near net-zero building, with a radiant floor cooling system with limited peak perimeter cooling capacity. **The client demands a highly glazed façade to meet competitive market needs, and requires that comfort conditions be maintained in immediate proximity to the glazing to maximize rentable interior space.** A possible kit of parts includes: high performance glazing/framing, daylight redirecting technologies, dynamic glazing/shading, all coupled to smart lighting controls and responsive HVAC controls. But **numerous challenges arise that simulation tools alone cannot fully solve:** for example: can the radiant system handle peak cooling? How to optimize daylighting and glare tradeoffs by season and room location? How will occupants react to integrated controls?



Systems integration issues measured in FLEXLAB.

Testbed Capabilities	Performance Parameters and Benefits
Complete photometric capture throughout the room with dynamic HDR capability	Visual comfort – contrast, glare, ability to maintain worksurface illuminance
Exterior daylight conditions–cloud cover, irradiance, sun position	Impact of exterior conditions
Lighting system and fixture power	System energy use, and peak demand; resolved fixture by fixture, time dependent correlated to daylight
HVAC energy use	Peak cooling measurements; HVAC energy impacts
Reconfigurable interior spaces	Impact of changing workstations for user location and orientation vs. windows
Optimization of shading devices and operation	Compare systems across cells; optimized control of shading systems on energy (cooling/lighting) and thermal/visual comfort
Robust data acquisition, accommodation of additional instrumentation	Flexibility to integrate experiment-specific measurement with existing testbed sensors
Ability to interoperate and execute control across a variety of platforms and devices	Flexibility to test diverse systems and components, control solutions, and proprietary systems



Time lapse of interior room luminance with dynamic shading.

Solution Pathway

To rapidly assess options, the design team, in coordination with the owner and key suppliers, conducts a series of tests in two testbeds, each with two experimental rooms, over a nine-month period that captures peak summer and winter test conditions. With four different design conditions, **the team focuses on two solutions that optimize cooling and make daylight secondary, and two other solutions that optimize daylighting**. One pathway explores fully dynamic shading solutions with electrochromic glazing and motorized exterior blinds, while the others provide low-SHGC glazing with manual blinds, with an active daylight control solution in the clerestory to daylight the full depth of the space. One of the testbeds is the rotating facility – which allows low-sun west-facing façades to be compared to south facades. Current performance vs. goals are tracked in real time using the LBNL-provided dashboards. **Once the design solutions have converged towards performance goals, a series of short-term experiments are made with staff occupying the spaces to assess comfort and acceptance.**

Immediate Outcomes

- **Verification of basis of design** and that 70% energy savings goal can be accomplished.
- Comparative performance data on key design options allowing different design decisions to be made for glazing, shading, lighting, and HVAC.
- **Incorporate sequence of operations specified for control of shading, lighting and HVAC** into design specs.
- Insights into product improvements for **next -generation product development**.
- **Validation of simulation tools** over large performance range.
- **Occupant feedback** on system components and operational issues.
- Guidance for interior designers; **operating manual for occupants** based on test results.

Extended Validation & Deployment Opportunities

- **Extend results to other orientations and other climates** using the virtual controls testbed and EnergyPlus tools.
- Advise ASHRAE 189, 90.1, LEED and **other mandatory and voluntary rating and code** bodies on issues of dynamic vs. static equipment and impact on achieving goals.
- Update **NFRC ratings and labeling programs** for commercial façades and windows.
- Explore variability of occupant response to a wider range of dynamic solutions and space layouts.
- Explore **alternate HVAC solutions** and integration schemes.
- Explore private office vs. open landscape design implications.
- Build partnerships with **early-adopter testbed members** to conduct scaled demonstrations in real-world buildings across the nation.

References and Further Reading

Lee, ES, Selkowitz, S, et al. High Performance Building Facade Solutions. PIER Final Project Report. 2009. LBNL-4583E. Available from: http://lowenergyfaçades.lbl.gov/

Konis, K, Lee, ES, Clear, RD. 2010. Visual Comfort Analysis of Innovative Interior and Exterior Shading Systems for Commercial Buildings using High Resolution Luminance Images. Leukos, Journal of the Illuminating Engineering Society of North America 7(3): 167-188. LBNL-4417E.

FLEXLAB

Facility for Low Energy eXperiments in Buildings

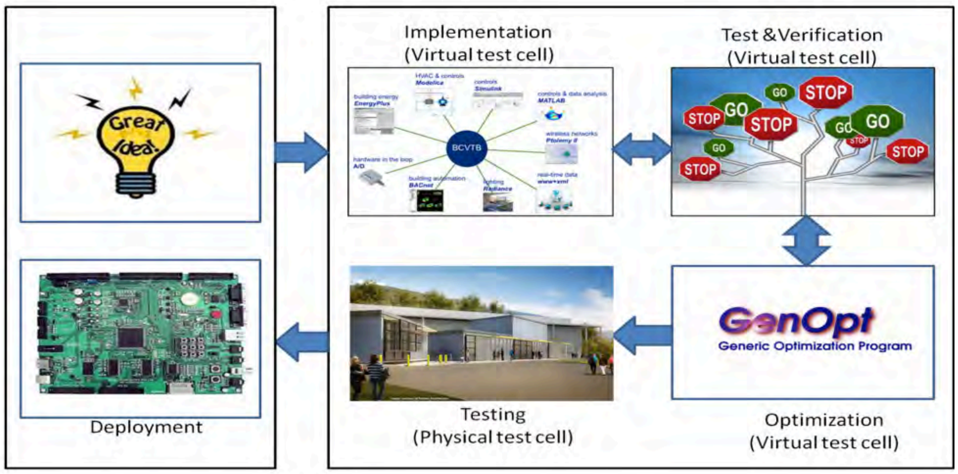
FLEXLAB for Model Based Controls – Use Case

Development of innovative controls algorithms for complex façade systems

The Challenge

Although there exist a large number of complex façade systems for reduction of solar heat gains in buildings, there is still a lack of innovative control algorithms capable of delivering high-quality, low-energy solutions.

FLEXLAB offers a unique opportunity for industry and researchers to collaboratively solve 'stretch' problems of this type by providing them a platform that can be used to develop, test and optimize innovative controls algorithms for complex façade systems.



A computer-based virtual testbed is part of the available FLEXLAB resources. This virtual testbed incorporates Modelica models as software for implementation, testing, verification and optimization of innovative controls algorithms for complex façade systems.

Starting Point

A controls company approaches LBNL with an idea to evaluate and optimize an innovative control algorithm for active façades before commercialization and deployment.

Solution Pathway

The controls engineer verifies the correct operation of the control algorithm, offline, in a computer-model of a test cell. Since validated Modelica models for each test cell are available, one only needs to implement the controls algorithm for performance verification. The model is then used to further improve the algorithm, running annual simulations in a minute's time, thus allowing for multiple design iterations. Once the algorithm performs satisfactorily in simulation, the controls engineer automatically generates C code from the Modelica model to implement on actual control hardware. LBNL developed software is then used to link the control hardware to the computer model of the desired test cell. This real-time implementation of physical hardware may have communication delays and signal quantification errors that were not part of the simulation model. Once the test implementation is successful, a three-months field performance test is conducted, in which the algorithm controls the façade systems of the physical test cell. The experiment is analyzed in real-time and compared to simulated reference data to identify and correct possible experimentation. Using physical measurements, the model is recalibrated and used to assess economic and energy benefits across different climate zones. Finally, the algorithm is commercialized, and results from the measurements are used to illustrate and explain the performance of the algorithm to customers.

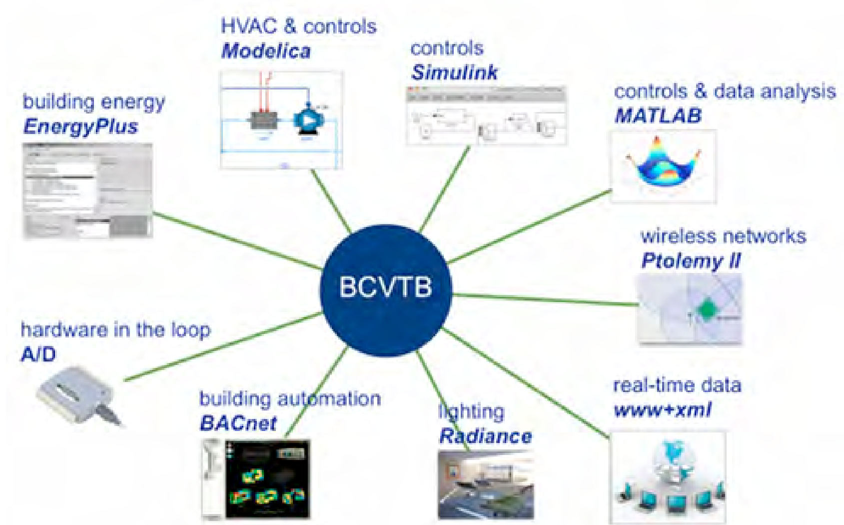
Testbed Capabilities	Performance Parameters and Benefits
Buildings simulation models	EnergyPlus/Modelica/Radiance tools to model control strategies, lighting/HVAC, and whole "testbed" energy use
Hardware-in-the-loop simulation tools	Virtual test-bed to link different simulation tools during run-time and link simulation tools with real hardware
HVAC control and energy use	Zonal load measurement
Robust data acquisition system to accommodate additional instrumentation	Flexibility to integrate experiment-specific measurement hardware with existing testbed instrumentation

Immediate Outcomes

- Developed and optimized control algorithms for active façades that achieve energy savings in buildings.
- Holistic archival set of high-quality field-measured data for use in manufacturer documentation and publications.
- Test-bed results and information to adjust system control logic, or component performance, if energy or comfort performance is lower than target.

Extended Validation & Deployment Opportunities

- Use of field-measured data and virtual testing to simulate and extrapolate findings to diverse climates, room geometries, envelope types, HVAC systems, and whole-building performance.
- Partner with LBNL researchers with subject matter expertise.
- Use the virtual testbed to conduct optimization in virtual environment prior to time-consuming full-scale testing.
- Use the virtual testbed for hardware-in-the-loop simulation for verification and real-time monitoring.



Integration of various modeling software for developing and testing control algorythms in the virtual testbed prior to testing in the physical testbed.

References and Further Reading

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Wetter, M. Modelica-based Modeling and Simulation to Support Research and Development in Building Energy and Control Systems. *Journal of Building Performance Simulation*, 2(2):143-161, 2009.
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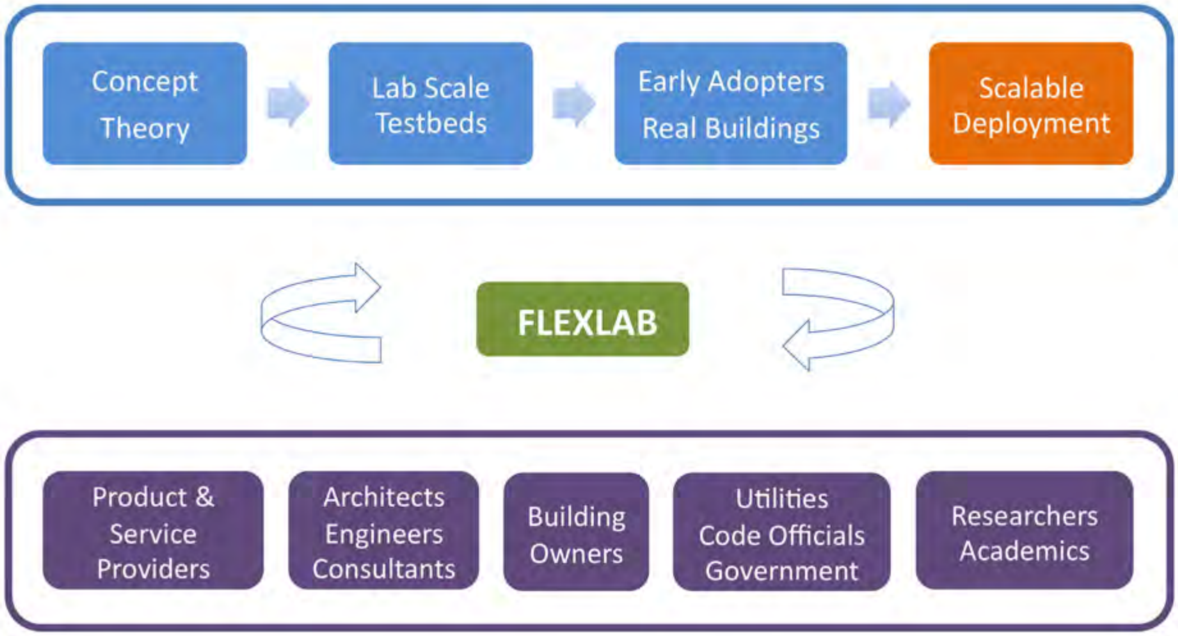

Get Involved

The buildings industry will benefit from partnering with FLEXLAB at the Berkeley Lab.

Product & Service Providers
- More rapidly design, prototype and test new energy-efficient products and systems
- Receive feedback on system performance that will allow for design optimization
- Harvest performance data that drives increased investment in new technologies and systems
- Access to industry professionals for input on industry pain-points, deployment potential, and barriers to implementation
- Send visiting researcher for collaborative research with the Berkeley Lab
- Power to leverage investment with government and utility research grants
- Access to early adopters for emerging technology implementation

Architects, Engineers, & Consultants
- Specify new innovative systems with confidence, thereby achieving higher energy performance targets
- Provide information on current deficiencies and needs in retrofit & new construction of energy-efficient buildings
- Participate in design and analysis of early adoption beta sites
- Provide expert advice on feasibility and barriers to innovative systems and technologies and jointly develop research goals
- Contribute to development of performance targets used for ‘technology challenge’ criteria (i.e. 1kw/sf lighting retrofit)
- Participate in quarterly meetings on research agenda, industry trends, and recent findings
- Train staff in cutting edge modeling & virtual design practices
- Gain insight and influence on regulatory and utility incentive trends

Building Owners
- Reduce financial risk of portfolio-wide energy efficiency implementation
- Increased confidence in investing in high efficiency retrofit solutions and new buildings
- Provide information on current deficiencies and needs in retrofit & new construction of energy-efficient buildings
- Actively contribute development of performance targets used for ‘technology challenges’
- Implement successful products/strategies in pre-determined ‘early adoption’ square footage
- Contribute to R&D agenda, and development of performance metrics used to evaluate control strategies and emerging technologies

Utilities, Code Officials, & Government
- Ability to more accurately predict EE program impacts
- Ability to tighten existing codes or offer new rebates and incentives based on confidence in measured performance data under realistic conditions
- Validate emerging technologies

Researchers & Academics
- Access to high-quality performance data to advance R&D in new technology
- Validation of simulation tools and methods
- Insights into new breakthrough opportunities

For more information on FLEXLAB or opportunities to partner with the Berkeley Lab please contact us:

BERKELEY LAB

Oren Schetrit
oschetrit@lbl.gov
510-486-5649
www.lbl.gov
flexlab.lbl.gov

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